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Case Study

Prioritization of Green Supplier Selection Attributes Using Fuzzy Extent Analysis: A Case Study of Iranian Cosmetics Industry

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Abstract

The environmental considerations have gained increasing attention both from industry practices and academic research over the past three decades. Selection and cooperation with appropriate suppliers have become strategically important in the cosmetics' industry, too. There are various publications concerning green supplier selection and evaluation in general. However, a review on the supplier selection literature focusing on cosmetics industry shows a poor attention to "Green" criteria. Hence, the novelty of the paper is concentrating on this question: what are the most important criteria for "Green" evaluation and selection of the suppliers in the "Cosmetics" industry. Due to the inherent uncertainty in subjective opinions of the industry experts, the Fuzzy Extent Analysis and Delphi methods were applied. Finally, this study aims at identifying and prioritizing the supplier selection measurement indicators with environmental concerns under uncertain conditions in the Iranian Cosmetics Industry. The preferences of experts over the attributes were gathered using a pairwise comparison-based questionnaire. The hierarchical clustered representation of the four main attributes; Quality, Risk, on time delivery, environment; and their importance weights were achieved as the result of the study.

Keywords: Green Supplier Selection; Fuzzy Extent Analysis; Cosmetics Industry; Prioritization.

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Introduction and Literature Review

Since the development of supply chain concept in the late 1970s, nothing has attracted the governments, corporate executives, and the public as much as the design of green supply chains. The green supply chain is the most important tool for organizations to adapt their activities to the environment. Not only governments and corporations but also consumers care about environmental issues; customers pay attention to environmental factors in addition to traditional factors when selecting and buying products. Therefore, any effort to improve the compatibility of the production process with environmental factors can also increase the general popularity and improve the business brand credibility. Especially in the cosmetics industry, a strong and proportional brand personality can drive customers towards product use, because the person has the feeling that the brand personality is reminiscent of and appealing to his own personality (Gholamreza Tehrani, Asadollah, Mohebbi, & Azizi, 2020).

In traditional supply chains, the flow of materials and information is usually from one end of the chain to the other. Participation and transparency in such chains are usually low, and organizations have little knowledge of the environmental issues of other supply chain partners. However, in a green supply chain, in order to oblige and encourage suppliers to accept and comply with environmental standards, it is necessary for the organization to provide some technical, organizational and financial support to its suppliers. On the other hand, the organization should lead suppliers to accept environmental criteria by adding provisions in accordance with environmental requirements to procurement contracts and considering new criteria for selecting a supplier. In this regard, the organization should ensure environmental compliance by conducting environmental audits at the time of selection and also during the time of cooperation with suppliers. Although this process can significantly improve the organization's environmental performance, it may result in fewer eligible candidate suppliers.

Achieving green supply chain goals is not possible without the active and sustainable participation of suppliers. Therefore, organizations must pay special attention to the supplier selection process to achieve their environmental goals. The purpose of selecting green suppliers is to identify suppliers with the highest potential to meet the company's requirements in an environmentally friendly manner. There are various criteria in the literature for the selection of suppliers traditionally and also with environmental considerations, which are reviewed and categorized in Table 1.

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Table 1. General and Green supplier selection attributes in the literature

General Attributes	References
Quality, delivery, historical performance, production facilities and capacity, net price, technological capabilities	(Dickson, 1966)
Performance, finance, technology, organizational culture and strategy	(Ellram, 1990)
Price, delivery, quality, capacity and facilities, geographical location, technological capability	(Weber, Current, & Benton, 1991)
Finance, price, quality, delivery, technology, capability, business communication history	(Cusumano & Takeishi, 1991)
Quality, ability to deliver, price feedback	(Chaudhry, Forst, & Zydiak, 1993)
Product, usability, degree of reliability, experience, price	(Swift, 1995)
Finance, Agreement, Communication, Flexibility, Technological Capability, Service, Reliability, Price	(Choi & Hartley, 1996)
Cost, quality, service	(Ghodsypour & O'Brien, 1998)
Quality level, production capacity, delivery time, warehouse capacity	(Jayaraman, Srivastava, & Benton, 1999)
Cost, quality, delivery, service	(Lee, Ha, & Kim, 2001)
Quality, delivery, technological facilities	(Muralidharan, Anantharaman, & Deshmukh, 2001)
Quality, Delivery, Price, Technological Capability, Financial Situation, Past Performance, Facility, Flexibility, Service	(Muralidharan, Anantharaman, & Deshmukh, A multi-criteria group decision making model for supplier rating, 2002)
Product performance, service, cost	(Kahraman, Cebeci, & Ulukan, 2003)
Service, Compatibility, Financial Stability, Performance, Price, Physical Equipment, Quality, Organizational Strategies, Trust	(Bottani & Rizzi, 2006)
Research and development, cost, quality, responsibility	(Chang, Wang, & Wang, 2007)
Cost, quality, delivery, service	(Celebi & Bayraktar, 2008)
Experience, financial strength, management stability, installation costs, monthly costs, reliability, speed, security, availability, chain changes	(Amin & Razmi, 2009)
Cost, delivery, quality, service	(Wang, 2010)

Net price, quality, on time delivery	(Yücel & Güneri, 2011)
Cost, quality, logistics, technology	(Erdem & Göçen, 2012)
Process and product quality, service level, innovation management, financial position	(Bruno, Esposito, Genovese, & Passaro, 2012)
Level of trust, quality, cost, timely delivery, management and organization, financial	(Tahriri, Mousavi, Hozhabri Haghighi, & Zawiah Md Dawal, 2014)
Product volume, on-time delivery, payment method, supply diversity, reliability, work experience, emerging business relationship, management, geographical location	(Karsak & Dursun, 2014)
Green Attributes	References
Number of training hours (environmental) per employee, energy label, biodegradable, green packaging, chemical behavior, product label, personnel awareness programs, gas resources, safe water, Climate Wise eco label, Design for the environment, require periodic environmental inspections, list of hazardous chemicals, public disclosure of environmental records, harmful substances for the ozone layer, emissions and pollution (per unit of product), ozone depleters, recyclable items, Reconstruction / Reusable, Third Party Certificate (ECO Label), Landfill (Tons per Year), Total Energy Consumption, Secondary Markets for Waste Production, Resource Recovery and Energy Per Unit, Waste Return With reverse logistics programs, water pollution with toxic substances, ISO 14000, application of environmental standards, incineration, transportation of gaseous waste, risk of harmful elements	(Walton, Handfield, & Melnyk, 1998)
Product pollution, resource consumption, ecology, ratio of green customers to total customers, environmental management system, commitment of green supply chain managers, use of environmentally friendly materials, use of environmentally friendly technologies, Environmental training of employees	(Shen, Olfat, Govindan, Khodaverdi, & Diabat, 2013)
Pollution rate, clean technology usage, Waste disposal, Recycling rate, Renewable and non-renewable energy use	(Tabatabaei & Bazrkar, 2019)

The cosmetics market is one of the largest and most thriving markets in the world (Karami & Karami, 2021). Achieving competitive advantage in such market through selection and cooperation with appropriate suppliers has become strategically important in the cosmetics industry over the past two decades. In order to analyze and manage such an important issue with environmental considerations, the cosmetics manufacturing companies must identify and prioritize the related indicators first.

Although lots of work has been conducted to explore and explain the green supplier selection criteria, a review on the supplier selection researches focusing on cosmetics industry shows a poor attention to "Green" attributes identification and prioritization as illustrated in Table 2. So, given the importance of the environmental considerations, this question will arise: what are the most important criteria for green evaluation and selection of the suppliers in the cosmetics industry?

Due to the inherent uncertainty in subjective opinions of the industry experts, the Fuzzy Extent Analysis and Delphi methods were applied. This study aims at identifying and prioritizing the supplier selection measurement indicators with environmental concerns under uncertain conditions in the Iranian Cosmetics Industry.

Table 2. "Green" supplier selection attributes in cosmetics industry in the literature

Supplier Selection Attributes		Method	Case study	Reference
General	Green			
• Delivery time • Equity acceptance • Abiding by Laws, regulations, and standards • Health and security • Flexibility • Loyalty • Willingness to long-term participation • Accessibility and customers' support	-	QFD, ANP, and Mixed-Integer Programming	Cosmetic company	(Abbasi, Hosnavi, & Tabrizi, 2013)
• bid-oriented factors • exporter oriented factors • country of origin factors relationship factors • other external factors	-	Semi-structured interviews	importing Korean cosmetics	(Kim, 2019)
• Cost/Price • Delivery reliability • Quality • Flexibility and responsiveness	• Green competencies • Environment management system (EMS) • Pollution	Topsis	herbal cosmetics and personal care products	(Atthirawong, 2020)

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Supplier Selection Attributes		Method	Case study	Reference
General	Green			
• Service capability • Strategic alliance	control • Green image		from a Thai OTOP2 producer	
• Quality control system • Appropriate equipment for sustainable manufacturing • Suitable storage space • Packaging quality and transportation services • Appropriate quality management • Responsiveness • Sanitation in production operations • Distance between the company and its suppliers • Financial strength • Work experience • Production planning system • After-sale services • Maintenance management system • Professional workforce	-	A locally linear neuro-fuzzy model	Kaf company: a leading producer of cosmetic and hygienic products in Iran	(Vahdani, Iranmanesh, Mousavi, & Abdollahzade, 2012)
• Cost and price • Quality • Delivery speed and time delay reduction	-	Fuzzy VIKOR method	Cosmetics and sanitation industry	(Shariari & Pilevari, 2016)

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Supplier Selection Attributes		Method	Case study	Reference
General	Green			
• Customer Satisfaction • Flexibility • Commitment • Distribution • After sales service • Production capacity				

Research Methodology

The research methodology can be shown in the general framework of Figure 1.

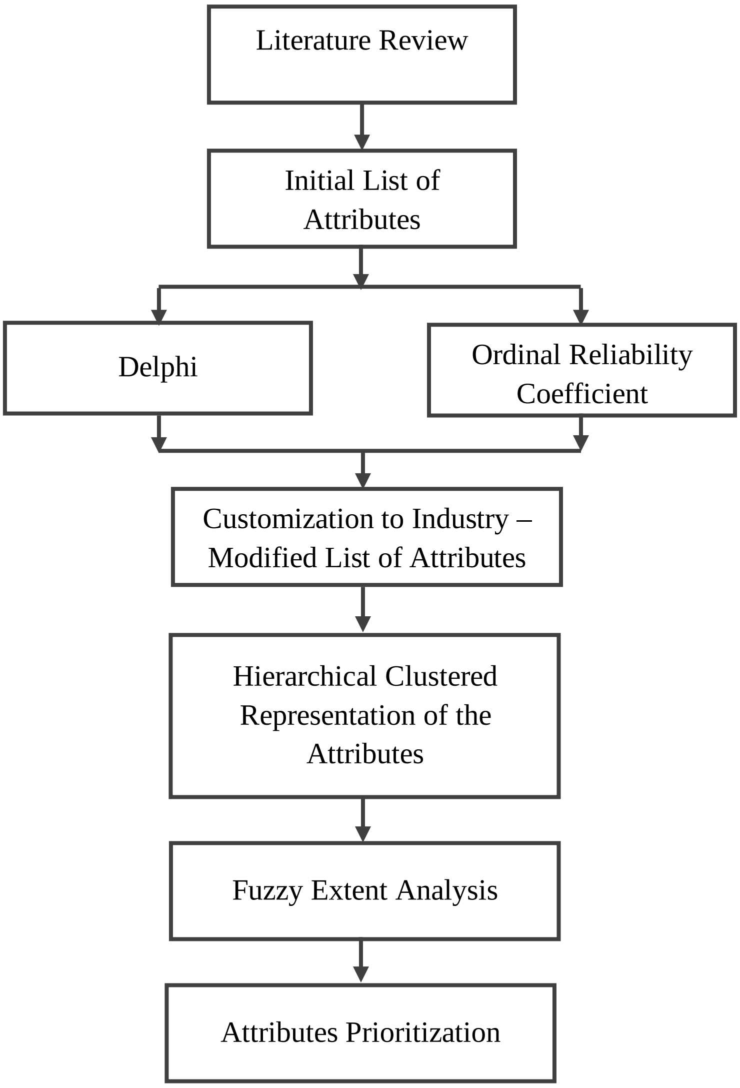

Figure 1. Research methodology and its steps

An initial list of criteria can be extracted from the literature review and adapted to the cosmetics industry according to expert opinions via Delphi technique. Delphi is one of the common formal consensus methods. It was developed in the 1960s by the Rand Corporation (Dabbaghi & Dehghan, 2019). The method used to arrive at a group opinion or decision and also assist structure the group communication processes based on an iteration approach (Aghajanian & SeyedAliAkbar, 2015). The experts respond to several rounds of questionnaires, and it continues until a level of agreement reaches (Cheng & Lin, 2002).

Since the preference information on the green supplier selection attributes belongs to the decision-makers' (DMs) subjective judgments and cannot be estimated by an exact numerical value, uncertainty approaches have been adopted in this paper. Besides, Delphi technique have been utilized a means of reaching a group consensus through multiple rounds. Fuzzy theory is one of the most-often applied theories and methods employed in such uncertainties (Sadeghieh, Dehghanbaghi, Dabbaghi, & Barak, 2012). A fuzzy extent analysis was used to conduct the attributes prioritization.

In the following, the outlines of the fuzzy extent analysis method are given based on (Bozbura & Beskese, 2007):

Let $X = \{x_1, x_2, x_3, \dots, x_n\}$ be an object set, and $U = \{u_1, u_2, u_3, \dots, u_n\}$ be a goal set. Based on each goal, m extent analysis values can be calculated for each object $M_{g_i}^1, M_{g_i}^2, \dots, M_{g_i}^m,\ \ i = 1,2, \dots, n$. All the $M_{g_i}^j\ (j = 1,2, \dots, m)$ are triangular fuzzy numbers.

Step1.

The fuzzy synthetic extent can be calculated using Eq (1).

$$S_i = \sum_{j=1}^{m} M_{g_i}^j \otimes \left[\sum_{i=1}^{n}\sum_{j=1}^{m} M_{g_i}^j\right]^{-1} \tag{1}$$

M extent analysis values for a particular matrix should be added to obtain $\sum_{j=1}^{m} M_{g_i}^j$ based on Eq (2).

$$\sum_{j=1}^{m} M_{g_i}^j = \left(\sum_{j=1}^{m} a_{ij}, \sum_{j=1}^{m} b_{ij}, \sum_{j=1}^{m} c_{ij}\right), \qquad i = 1,2, \dots, n \tag{2}$$

$M_{g_i}^j\ (j = 1,2, \dots, m)$ values should be added to obtain $\left[\sum_{i=1}^{n}\sum_{j=1}^{m} M_{g_i}^j\right]^{-1}$ based on Eq (3).

$$\sum_{i=1}^{n}\sum_{j=1}^{m} M_{g_i}^j = \left(\sum_{i=1}^{n}\sum_{j=1}^{m} a_{ij}, \sum_{i=1}^{n}\sum_{j=1}^{m} b_{ij}, \sum_{i=1}^{n}\sum_{j=1}^{m} c_{ij}\right) \tag{3}$$

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And the inverse of the mentioned vector can be computed based on Eq (4).

$$\left[\sum_{i=1}^{n}\sum_{j=1}^{m} M_{g_i}^{j}\right]^{-1} = \left(\frac{1}{\sum_{i=1}^{n}\sum_{j=1}^{m} c_{ij}}, \frac{1}{\sum_{i=1}^{n}\sum_{j=1}^{m} b_{ij}}, \frac{1}{\sum_{i=1}^{n}\sum_{j=1}^{m} a_{ij}}\right) \tag{4}$$

Step 2.

The degree of possibility of $M_2 = (a_2, b_2, c_2) \geq M_1 = (a_1, b_1, c_1)$ is defined using Eq (5).

$$V(M_2 \geq M_1) = \underset{y \geq x}{sup}\left[min\left(\mu_{M1}(x), \mu_{M1}(y)\right)\right] \tag{5}$$

Step 3.

The normalized weight vectors are defined using Eq (6).

$$\mathrm{W} = (\mathrm{d}(\mathrm{A}_1), \mathrm{d}(\mathrm{A}_2), \ldots \mathrm{d}(\mathrm{A}_\mathrm{n}))^\mathrm{T} \tag{6}$$

Where W is a non-fuzzy number.

Application: Cosmetics Industry case

Selection and cooperation with appropriate suppliers have become strategically important in the cosmetics industry in recent two decades. In this research, the cosmetics industry in Iran has been studied. This study was conducted with the focus on one of the companies supplying and producing cosmetics. The company is registered as one of the largest manufacturers in this industry and has been operating in this industry for more than eighteen years. The company offers its various products in four groups of skin, hair, cosmetics and perfume products and in two sections for men and women. These products are produced in three different brands and are widely marketed throughout the country. In more than a decade of activity, this company has been able to be the largest manufacturer and distributor in the cosmetics industry. Due to confidentiality, the name of the company has been avoided in this study.

Considering the importance of suppliers in the production and supply of raw materials in this company, and as the main purpose of this research, important criteria were selected in order to evaluate suppliers in this industry. In this section, the results of applying the research steps (Figure 2) are presented step by step.

Using the literature review (Table 1), an initial list of green supplier evaluation attributes was prepared. In order to customize the list of attributes to the corporate needs and requirements, expert opinions were collected. Five company experts who were familiar with the industry needs have been carefully selected to ensure the comprehensiveness of the sample and the generalizability of the results.

The main research tool in this study was the questionnaire survey. Based on the initial list, the set of green supplier evaluation attributes were considered in the form of

a semi-structured questionnaire. In the first round of the Delphi, the preference of the experts over the attributes was gathered with the 5-point Likert scale. To investigate the reliability, we utilized R software and reported Ordinal Theta Coefficient (Hajhosseini, Hosseini Shabanan, Sadat Naji, & Naghsh, 2020) as shown in Table 3. Ordinal Theta Coefficient for all factors, indicating good internal validity. The Experts were also asked to categorize the provided attributes. Based on the collected data and the calculations in each round, each expert was asked to modify his opinion as a result of considering the views of their peers in the panel. The Delphi rounds continue until the expected level of agreement is reached. The Modified List of Attributes is shown in Figure 2.

Table 3. the reported Ordinal Theta Coefficient

Ordinal Theta if a Question Deleted	New Theta
Without Question 1	0.813298
Without Question 2	0.811141
Without Question 3	0.815389
Without Question 4	0.851330
Without Question 5	0.807052
Without Question 6	0.792577
Without Question 7	0.805624
Without Question 8	0.768899
Without Question 9	0.788479
Without Question 10	0.761354
Without Question 11	0.860319
Without Question 12	0.776699
Without Question 13	0.846416
Without Question 14	0.815889
Without Question 15	0.814072
Without Question 16	0.822899
Without Question 17	0.785284
Without Question 18	0.820025
Ordinal Theta for all Question= 0.812303	

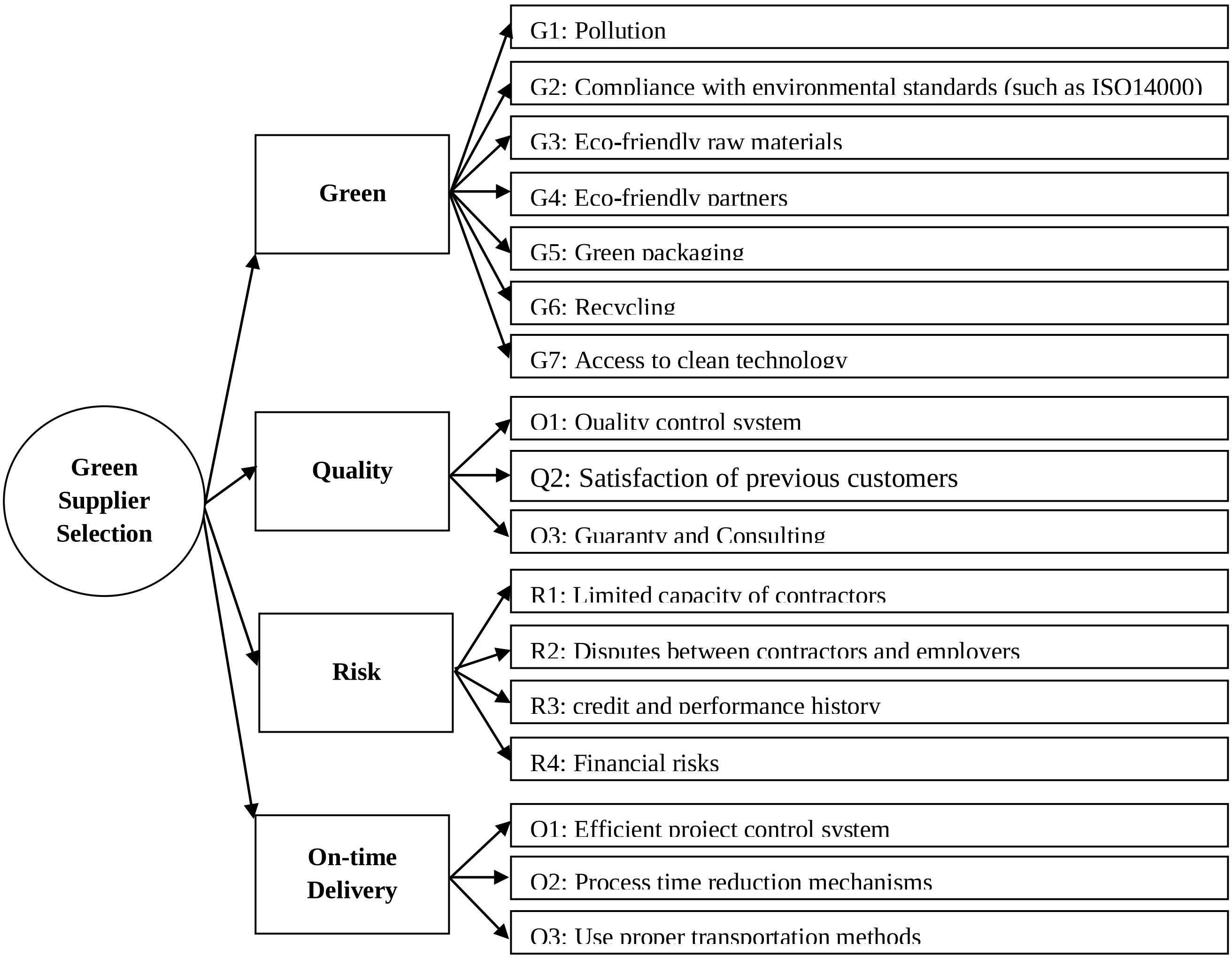

Figure 2. Hierarchical clustered representation of the attributes

The fuzzy extent analysis steps, as mentioned in Section 2, were applied to prioritize the attributes. The preferences of the experts about each attribute were gathered by triangular fuzzy numbers and via pair wise comparisons questionnaire. The results are shown in Table 4, 5, 6, 7.

Table 4. pair-wise comparisons for "Green" sub-attributes

Green	G1	G2	G3	G4	G5	G6	G7
G1	(1,1,1)	(1,3/2,2)	(1,3/2,2)	(1/2,1,3/2)	(1/2,1,3/2)	(1,3/2,2)	(3/2,2,5/2)
G2	(1/2,2/3,1)	(1,1,1)	(1,3/2,2)	(1/2,2/3,1)	(1,3/2,2)	(1,3/2,2)	(3/2,2,5/2)
G3	(1/2,2/3,1)	(1/2,2/3,1)	(1,1,1)	(1/2,2/3,1)	(1/2,2/3,1)	(1,3/2,2)	(3/2,2,5/2)
G4	(2/3,1,2)	(1,3/2,2)	(1,3/2,2)	(1,1,1)	(1/2,2/3,1)	(1,3/2,2)	(3/2,2,5/2)
G5	(2/3,1,2)	(1/2,2/3,1)	(1,3/2,2)	(1,3/2,2)	(1,1,1)	(1,3/2,2)	(1,3/2,2)
G6	(1/2,2/3,1)	(1/2,2/3,1)	(1/2,2/3,1)	(1/2,2/3,1)	(1/2,2/3,1)	(1,1,1)	(1/2,1,3/2)
G7	(2/5,1/2,2/3)	(2/5,1/2,2/3)	(2/5,1/2,2/3)	(2/5,1/2,2/3)	(1/2,2/3,1)	(2/3,1,2)	(1,1,1)

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Table 5. pair-wise comparisons for "Risk" sub-attributes

Risk	R1	R2	R3	R4
R1	(1,1,1)	(2/3,1,2)	(1/2,2/3,1)	(1,1,1)
R2	(1/2,1,3/2)	(1,1,1)	(2/3,1,2)	(1/2,1,3/2)
R3	(1,3/2,2)	(1/2,1,3/2)	(1,1,1)	(1,3/2,2)
R4	(1,1,1)	(2/3,1,2)	(1/2,2/3,1)	(1,1,1)

Table 6. pair-wise comparisons for "On time delivery" sub-attributes

On time delivery	O1	O2	O3
O1	(1,1,1)	(1,3/2,2)	(1,3/2,2)
O2	(1/2,2/3,1)	(1,1,1)	(1/2,2/3,1)
O3	(1/2,2/3,1)	(1,3/2,2)	(1,1,1)

Table 7. pair-wise comparisons for "Quality" sub-attributes

Quality	Q1	Q2	Q3
Q1	(1,1,1)	(3/2,2,5/2)	(1/2,1,3/2)
Q2	(2/5,1/2,2/3)	(1,1,1)	(3/2,2,5/2)
Q3	(2/3,1,2)	(2/5,1/2,2/3)	(1,1,1)

Step 1.

$$\sum_{j=1}^{m} M_{g_i}^{j} = (\sum_{j=1}^{m} a_{ij}, \sum_{j=1}^{m} b_{ij}, \sum_{j=1}^{m} c_{ij}), i = 1,2,3,...,n$$

$$\sum_{j=1}^{7} M_{g_1}^{j} = (6.5, 9.5, 12.5)$$

$$\sum_{j=1}^{7} M_{g_2}^{j} = (6.5, 8.8333, 11.5)$$

$$\sum_{j=1}^{7} M_{g_3}^{j} = (5.5, 7.1667, 9.5)$$

$$\sum_{j=1}^{7} M_{g_4}^{j} = (6.6667, 9.1667, 12.5)$$

$$\sum_{j=1}^{7} M_{g_5}^{j} = (6.1667, 8.6667, 12)$$

$$\sum_{j=1}^{7} M_{g_6}^{j} = (4, 5.3333, 7.5)$$

$$\sum_{j=1}^{7} M_{g_7}^{j} = (3.7667, 4.6667, 6.6667)$$

$$\left[\sum_{i=1}^{n}\sum_{j=1}^{m} M_{g_i}^{j}\right] = (\sum_{i=1}^{n}\sum_{j=1}^{m} a_{ij}, \sum_{i=1}^{n}\sum_{j=1}^{m} b_{ij}, \sum_{i=1}^{n}\sum_{j=1}^{m} c_{ij})$$

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$$\sum_{i=1}^{7}\sum_{j=1}^{7} M_{g_i}^{j} = (39.1001, 53.3334, 72.1667)$$

$$\left[\sum_{i=1}^{n}\sum_{j=1}^{m} M_{g_i}^{j}\right]^{-1} = \left(\frac{1}{\sum_{i=1}^{n}\sum_{j=1}^{m} c_{ij}}, \frac{1}{\sum_{i=1}^{n}\sum_{j=1}^{m} b_{ij}}, \frac{1}{\sum_{i=1}^{n}\sum_{j=1}^{m} a_{ij}}\right)$$

$$\left[\sum_{i=1}^{7}\sum_{j=1}^{7} M_{g_i}^{j}\right]^{-1} = \left(\frac{1}{72.1667}, \frac{1}{53.3334}, \frac{1}{39.1001}\right)$$

$$S_i = \sum_{j=1}^{m} M_{g_i}^{j} \otimes \left[\sum_{i=1}^{n}\sum_{j=1}^{m} M_{g_i}^{j}\right]^{-1}$$

$$S_1 = (6.5, 9.5, 12.5) \otimes \left(\frac{1}{72.1667}, \frac{1}{53.3334}, \frac{1}{39.1001}\right) = (0.0901, 0.1781, 0.3197)$$

$$S_2 = (6.5, 8.8333, 11.5) \otimes \left(\frac{1}{72.1667}, \frac{1}{53.3334}, \frac{1}{39.1001}\right) = (0.0901, 0.1656, 0.2941)$$

$$S_3 = (5.5, 7.1667, 9.5) \otimes \left(\frac{1}{72.1667}, \frac{1}{53.3334}, \frac{1}{39.1001}\right) = (0.0762, 0.1344, 0.2430)$$

$$S_4 = (6.6667, 9.1667, 12.5) \otimes \left(\frac{1}{72.1667}, \frac{1}{53.3334}, \frac{1}{39.1001}\right) = (0.0924, 0.1719, 0.3197)$$

$$S_5 = (6.1667, 8.6667, 12) \otimes \left(\frac{1}{72.1667}, \frac{1}{53.3334}, \frac{1}{39.1001}\right) = (0.0855, 0.1625, 0.3069)$$

$$S_6 = (4, 5.3333, 7.5) \otimes \left(\frac{1}{72.1667}, \frac{1}{53.3334}, \frac{1}{39.1001}\right) = (0.0554, 0.1, 0.1918)$$

$$S_7 = (3.7667, 4.6667, 6.6667) \otimes \left(\frac{1}{72.1667}, \frac{1}{53.3334}, \frac{1}{39.1001}\right) = (0.0522, 0.0875, 0.1705)$$

Step2.

$$V(M_2 \geq M_1) = Sup[\min(\mu_{M_1}(x), \mu_{M_2}(y))], y \geq x$$

$V(S_1 \geq S_2) = 1$ $\quad ,V(S_1 \geq S_3) = 1$ $\quad ,V(S_1 \geq S_4) = 1$

$V(S_1 \geq S_5) = 1$ $\quad ,V(S_1 \geq S_6) = 1$ $\quad ,V(S_1 \geq S_7) = 1$

$V(S_2 \geq S_1) = 0.9423$ $\quad ,V(S_2 \geq S_3) = 1$ $\quad ,V(S_2 \geq S_4) = 0.9697$

$V(S_2 \geq S_5) = 1$ $\quad ,V(S_2 \geq S_6) = 1$ $\quad ,V(S_2 \geq S_7) = 1$

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$V(S_3 \geq S_1) = 0.7777$, $V(S_3 \geq S_2) = 0.8305$, $V(S_3 \geq S_4) = 0.8006$

$V(S_3 \geq S_5) = 0.8486$, $V(S_3 \geq S_6) = 1$, $V(S_3 \geq S_7) = 1$

$V(S_4 \geq S_1) = 0.9737$, $V(S_4 \geq S_2) = 1$, $V(S_4 \geq S_3) = 1$

$V(S_4 \geq S_5) = 1$, $V(S_4 \geq S_6) = 1$, $V(S_4 \geq S_7) = 1$

$V(S_5 \geq S_1) = 0.9329$, $V(S_5 \geq S_2) = 0.9859$, $V(S_5 \geq S_3) = 1$

$V(S_5 \geq S_4) = 0.9580$, $V(S_5 \geq S_6) = 1$, $V(S_5 \geq S_7) = 1$

$V(S_6 \geq S_1) = 0.5803$, $V(S_6 \geq S_2) = 0.6221$, $V(S_6 \geq S_3) = 0.7799$

$V(S_6 \geq S_4) = 0.5952$, $V(S_6 \geq S_5) = 0.6431$, $V(S_6 \geq S_7) = 1$

$V(S_7 \geq S_1) = 0.4702$, $V(S_7 \geq S_2) = 0.5073$, $V(S_7 \geq S_3) = 0.6678$

$V(S_7 \geq S_4) = 0.4806$, $V(S_7 \geq S_5) = 0.5313$, $V(S_7 \geq S_6) = 0.9020$

$$d'(A_i) = \min V(S_i \geq S_k)$$

$$d'(A_1) = \min V(S_1 \geq S_k) = 1 \quad , k = 2,3,4,5,6,7$$

$$d'(A_2) = \min V(S_2 \geq S_k) = 0.9423 \quad , k = 1,3,4,5,6,7$$

$$d'(A_3) = \min V(S_3 \geq S_k) = 0.7777 \quad , k = 1,2,4,5,6,7$$

$$d'(A_4) = \min V(S_4 \geq S_k) = 0.9737 \quad , k = 1,2,3,5,6,7$$

$$d'(A_5) = \min V(S_5 \geq S_k) = 0.9329 \quad , k = 1,2,3,4,6,7$$

$$d'(A_6) = \min V(S_6 \geq S_k) = 0.5803 \quad , k = 1,2,3,4,5,7$$

$$d'(A_7) = \min V(S_7 \geq S_k) = 0.4702 \quad , k = 1,2,3,4,5,6$$

Step 3.

$$W' = (1, 0.9423, 0.7777, 0.9737, 0.9329, 0.5803, 0.4702)^T$$

The resulted prioritization of the attributes is reported in Table 8.

Table 8. Green supplier selection Attributes and their weights in cosmetics industry case

Category	Green supplier selection Attributes	Calculated weight
Green	G1: Pollution	0.1761
	G2: Compliance with environmental standards (such as ISO14000)	0.1661
	G3: Eco-friendly raw materials	0.137
	G4: Eco-friendly partners	0.1715
	G5: Green packaging	0.1643
	G6: Recycling	0.1022
	G7: Access to clean technology	0.0828
Quality	Q1: Quality control system	0.4075
	Q2: Satisfaction of previous customers	0.3474
	Q3: Guaranty and Consulting	0.2451
Risk	R1: Limited capacity of contractors	0.2244
	R2: Disputes between contractors and employers	0.2518
	R3: credit and performance history	0.2994
	R4: Financial risks	0.2244
On-time Delivery	O1: Efficient project control system	0.4495
	O2: Process time reduction mechanisms	0.2072
	O3: Use proper transportation methods	0.4333

Conclusions

Achieving green supply chain goals is not possible without the active selection and sustainable participation of suppliers. To evaluate suppliers, it is necessary to prepare a list of important criteria in the first step. In this paper, the green supplier selection attributes were listed by reviewing the literature. Then, Experts' opinions on the attributes were aggregated using the Delphi method. Due to the inherent uncertainty of preferences, the fuzzy extent analysis was utilized to prioritize and calculate the importance weight of attributes. Finally, seventeen criteria in four categories: Green, quality, risk and on-time delivery, were identified as green supplier selection attributes in the cosmetics industry in Iran.

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